DISSERTATION

CLOUD RADIATIVE FORCING
IN THE TROPICS

Submitted by

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In partial fulfillment of the requirements
for the Degree of Doctor Of Philosophy
Colorado State University
Fort Collins, Colorado
Fall 1995

ABSTRACT

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Understanding the role of clouds is one of the highest priority science objectives in the global climate change program. In particular there has been a renewed interest in understanding the cloud radiative interactions in the tropical regions. Although a number of studies have emphasized the importance of cloud optical properties on the earth's radiative energy balance, information concerning cloud optical depth and particle size as a function of cloud type is lacking.

In this study, every fifth day from six months of collocated Advanced Very High Resolution Radiometer (AVHRR) Global Area Coverage (GAC) and the instantaneous scanner Earth Radiation Budget Experiment (ERBE) data from the NOAA-9 and NOAA-10 platforms are used to study the spectral and broadband properties of clouds over the tropical Pacific region. A sophisticated cloud masking technique is used

to separate clear from cloudy pixels. This new scene identification scheme then is used to invert the ERBE radiances to top of atmosphere (TOA) fluxes using angular dependence models (ADMs) developed as part of the ERBE program. The cloud optical depth and effective radii of water clouds are retrieved using Mie theory and the discrete ordinate model. Ice clouds are characterized as randomly oriented hexagonal ice crystals, and a monodisperse size distribution is assumed in order to simultaneously retrieve cloud optical depth and effective radii simultaneously using the discrete ordinate model. The relationship between AVHRR derived cloud liquid water path (LWP) and ERBE derived albedo as a function of effective radii is compared with two-stream model results. Using four-stream radiative transfer model results with hexagonal ice crystal parametrization, the relationship between ice water path (IWP) and cloud albedo is examined.

The results from this study indicate that there are significant differences between the AVHRR derived scene identification scheme and the existing ERBE scheme. The two schemes agree only 35% of the time for clear sky identification, with a 98% agreement for the overcast category. This shows the difficulty in using broadband scanner data to detect clear sky pixels.

Peak water cloud effective radii values are between 10-12 μm. which agrees well with previous studies. Comparison of satellite derived values and two-stream radiative transfer analysis shows that the AVHRR estimated water cloud particle sizes are larger than those predicted by theory. More validation studies along with 3-D radiative transfer analyses are necessary to further understand these relationships. Ice cloud effective radii have peak values between 11-25 μm with maximum values of up to 177 μm. The relationship between ERBE cloud albedo and AVHRR derived IWP as a function of effective radii qualitatively is in agreement with four-stream model results.

Six months of daytime analysis shows that the net radiative forcing of ice clouds in the tropics is largely negative and that this negative cloud forcing can be traced to large cloud optical thickness values. These net radiative forcing values are derived from instantaneous scanner observations. As such they should be interpreted with caution because they are not integrated over a twenty-four hour period. Previous studies by Ramanathan et al (1989a), and Harrison et al (1990) which were averaged over space and time indicate that the net forcing of all clouds in the tropics is close zero.

The day time 1985 and 1987 data show that as sea surface temperature (SST) increases. the cloud optical depth and IWP values increase. The implications are that warmer SST's produces colder clouds with large IWP's leading to negative net radiative forcing values This study contributes towards understanding the role of cloud optical properties on the top of atmosphere radiative energy budget. A coupling of the physical. dynamical and radiative processes are necessary in order to understand the role of clouds in regulating SST's in the tropics.

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FALL. 1995